A New Method for Calculating the Environmental Benefits of Clean Energy Technologies

Tom Kerr, Chief
Energy Supply & Industry Branch
US Environmental Protection Agency

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EPA's Objectives

- Quantify benefits of clean energy technologies (CET)
- Quantify benefits of energy efficiency technologies (EE)
- Assist CET/EE industries in marketing their technologies
- Develop impact estimates for EPA voluntary partnerships
- Encourage electricity consumers to reduce their environmental footprint
- Improve upon displaced emissions methodologies

Existing Methodologies

- Marginal unit emissions rate
  - Estimate displaced emissions based on emission rate of marginal unit
  - Analytically difficult to identify unit(s) or type of units displaced
- Average emissions rate
  - No direct correlation with displaced emissions
  - Baseload generation rarely displaced
- Estimates using historic data
  - May not be forward looking
  - Fails to account for future market adjustments

Key Issues In Determining Displaced Emissions

- Integrated approach required:
  - Account for fuel, capacity, generation, and emissions markets simultaneously
  - Recognize interconnected, forward-looking nature of power markets
- Interdependence of capacity and dispatch decisions:
  - Power markets simultaneously adjust generation and capacity in response to CET or EE
  - Displaced unit(s) not always the marginal generating unit
  - Often more than one unit is displaced
  - Capacity adjustment in long term is important
  - Displaced emissions depend on fuel and efficiency of displaced unit(s)

Key Issues (Cont'd)

- Geographic location of CET/EE impacts:
  - Electricity markets are highly integrated
  - Transmission flows are important consideration
  - Impacts may extend beyond region in which CET/EE penetrates
- Simultaneity of CET/EE impacts across regions:
  - Displaced emissions depend on demand/supply changes assumed in other regions
- Magnitude:
  - Displaced emissions *rate* varies with magnitude of penetration of CET or EE
  - Magnitude affects mix of displaced units

A New Approach

Average Displaced Emission Rate (ADER)

- Definition:
  - 'Parameter' for estimating how emissions change for each kWh change in electric demand or supply from CET/EE:

$$\text{ADER} = \left\{ \frac{\text{total displaced emissions (lbs.)}}{\text{displaced generation (kWh)}} \right\}$$

By year, geographic region and hour block

  - Applied to generation avoided (kWh) to derive estimate of displaced emissions

Key Features of ADER

- Accounts for generation and capacity changes
- Considers power market issues
- Considers emission characteristics of many types of generating units
- Provides estimates specific to hour block, year, and geographic region
- Based on simulations of impact of EE and CET using detailed power market model
- Reports emissions of CO2, Hg, SO2, NOx

Estimating ADER Parameters

- Analytical tool:
  - Integrated Planning Model (IPM®)
  - EPA Base Case 2000 assumptions and data
- Modeling approach:
  - ADER parameters estimated for each season, hour block, & geographic region
  - 26 model regions grouped into 5 geographic regions
  - Geographic regions analyzed individually, including interactions between regions
  - Displaced emissions estimated for 2005, 2010, 2015, 2020
- Each model run simulates representative levels of CET/EE penetration by:
  - Hour block
  - Season (summer/winter)
  - Geographic region

Hour Blocks Used for ADER

24 hour coverage

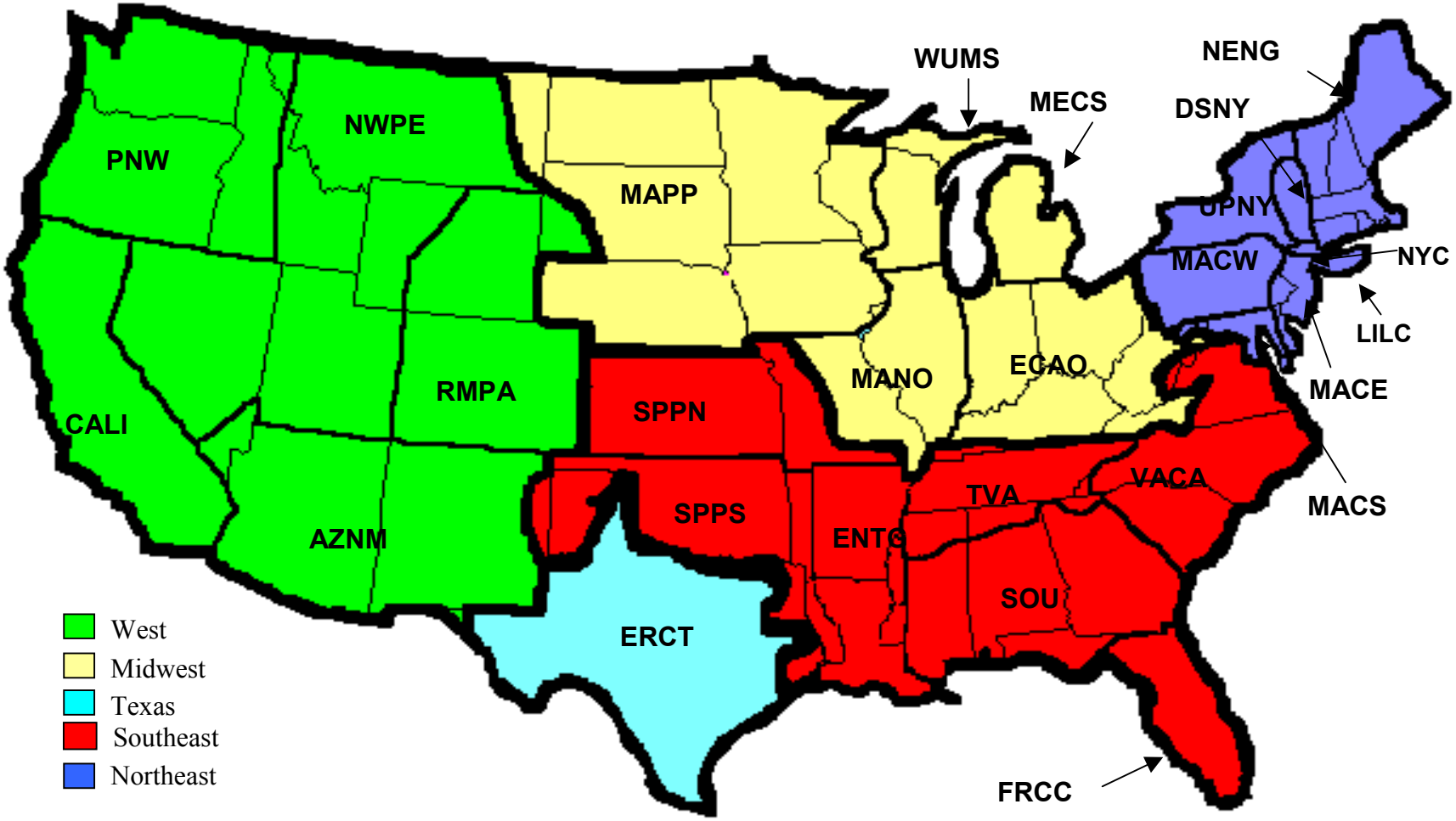
11 different hour blocks[1] include 2 seasons & 3 different representative day types:

- weekday
- peak-day
- weekend

[1]Hour Block 11 (not shown here) consists of hour blocks 2,3,7 and 8.

	Winter			Summer		
	Weekday	Peak Day	Weekend	Weekday	Peak Day	Weekend
12 AM - 1 AM	1	1	1	6	6	6
1 AM - 2 AM	1	1	1	6	6	6
2 AM - 3 AM	1	1	1	6	6	6
3 AM - 4 AM	1	1	1	6	6	6
4 AM - 5 AM	1	1	1	6	6	6
5 AM - 6 AM	4	4	1	9	9	6
6 AM - 7 AM	4	4	1	9	9	6
7 AM - 8 AM	2	2	5	7	7	10
8 AM - 9 AM	2	2	5	7	7	10
9 AM - 10 AM	2	2	5	7	7	10
10 AM - 11 AM	2	2	5	7	7	10
11 AM - 12 PM	2	2	5	7	7	10
12 PM - 1 PM	3	3	5	8	8	10
1PM - 2 PM	3	3	5	8	8	10
2 PM - 3 PM	3	3	5	8	8	10
3 PM - 4 PM	3	3	5	8	8	10
4 PM - 5 PM	3	3	5	8	8	10
5 PM - 6 PM	3	3	5	8	8	10
6 PM - 7 PM	3	3	5	8	8	10
7 PM - 8 PM	4	4	5	9	9	10
8 PM - 9 PM	4	4	5	9	9	10
9 PM - 10 PM	4	4	5	9	9	10
10 PM - 11 PM	1	1	1	6	6	6
11 PM - 12 AM	1	1	1	6	6	6

ADER Regions



Current ADER Load Shapes

Residential Energy Efficiency

Weatherization
Heating Upgrade
Cooling Upgrade
Thermostat Upgrade
New Home Overall Upgrade

Commercial Energy Efficiency

Lighting Upgrade
Plug Load Equipment Upgrade
Building Tune-up
Fans & Motors Upgrade
Plant Upgrade
Overall Upgrade

Industrial Energy Efficiency

Average

Clean Energy Technologies

Wind
Solar
Geothermal
Biomass
Combined Heat & Power

Illustration of ADER Estimate

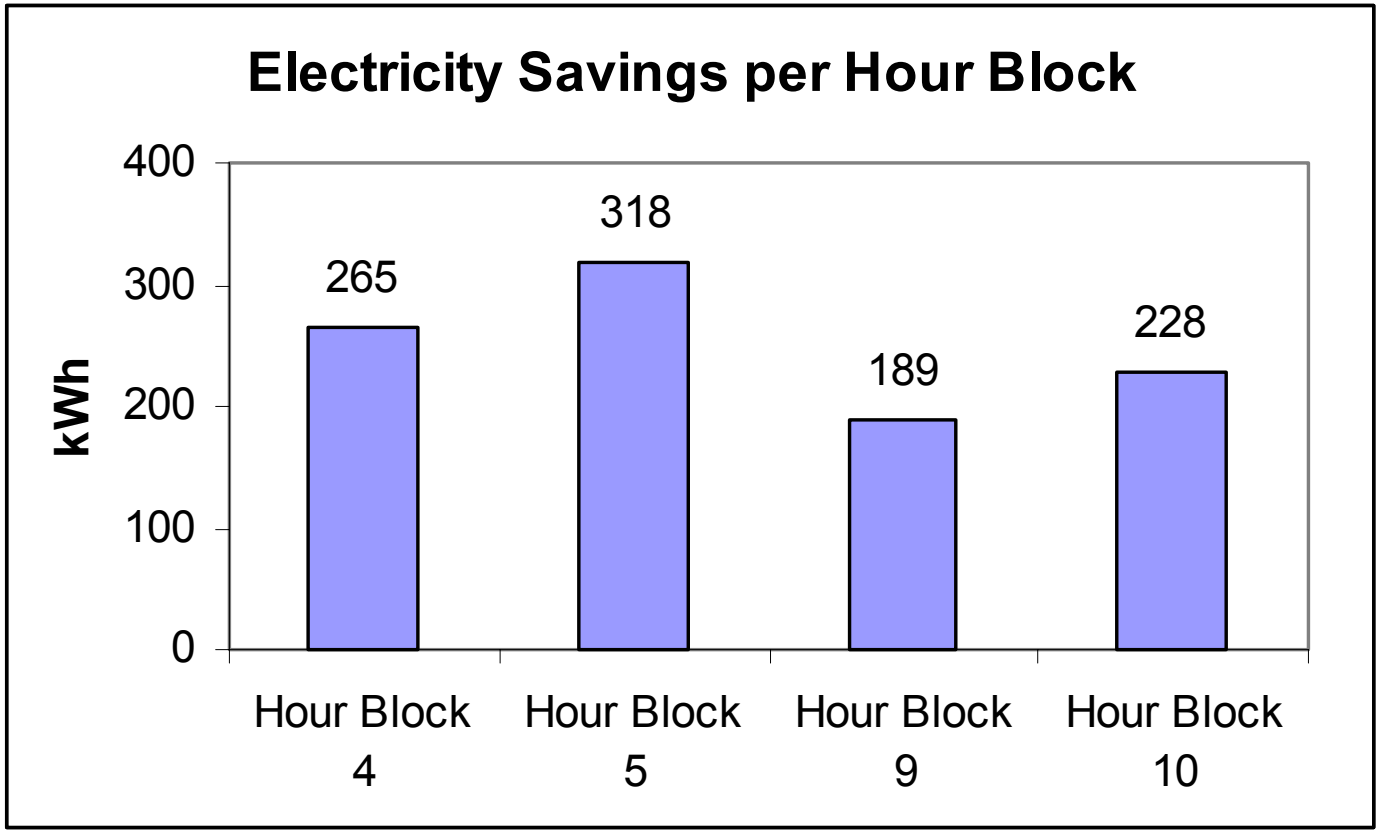
- Estimate displaced CO_2 emissions for an energy-efficient household appliance in the Northeast

- Estimation steps:
  - Step 1: Specify performance, operation, and location characteristics
  - Step 2: Select ADER parameters
  - Step 3: Estimate displaced emissions

Step 1: Determine the performance, operation, and location characteristics

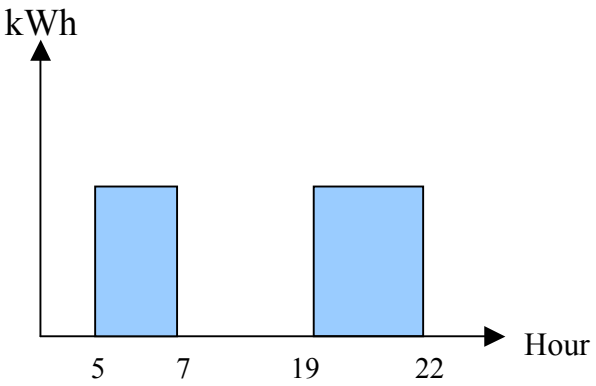
Technology:	Energy-efficient household appliance
Region of penetration:	Northeast
Year implemented:	2005
Savings year:	2010
Total energy saved:	1,000 kWh / year
Hours of operation:	Winter Weekdays and peak-days: ***Hour Block 4*** : 5 AM – 7 AM, 7 PM – 10 PM Winter Weekends: ***Hour Block 5*** : 7 AM – 10 PM Summer Weekdays and peak-days: ***Hour Block 9*** : 5 AM – 7 AM, 7 PM – 10 PM Winter Weekends: ***Hour Block 10*** : 7 AM – 10 PM

Electricity Savings by Hour Block



Step 2: Select ADER Parameters

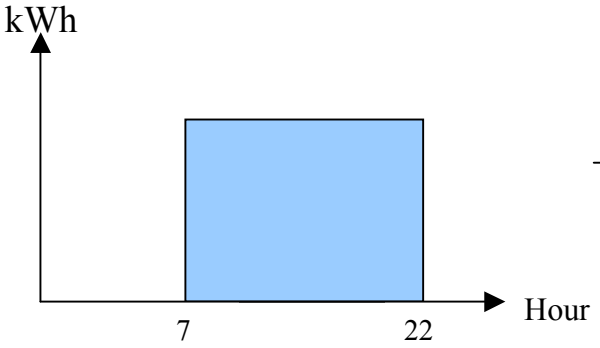
Hour Block 4, Winter Weekday and Peak Day



CO_2 ADER Parameters

Geographical Region	lbs/kWh
Northeast	-0.75
Midwest	0.21
Southeast	-0.02
Texas	0
West	0

Hour Block 5, Winter Weekend

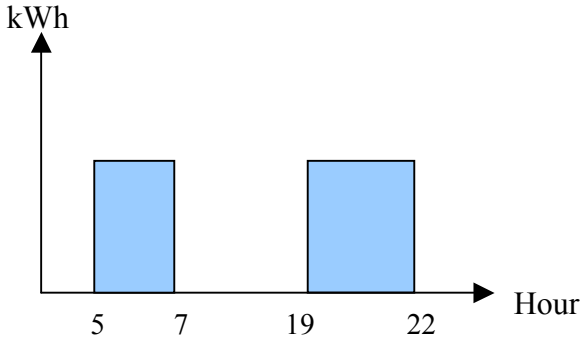


CO_2 ADER Parameters

Geographical Region	lbs/kWh
Northeast	-0.82
Midwest	0.18
Southeast	-0.03
Texas	0
West	0

Step 2: Select ADER Parameters (Cont'd.)

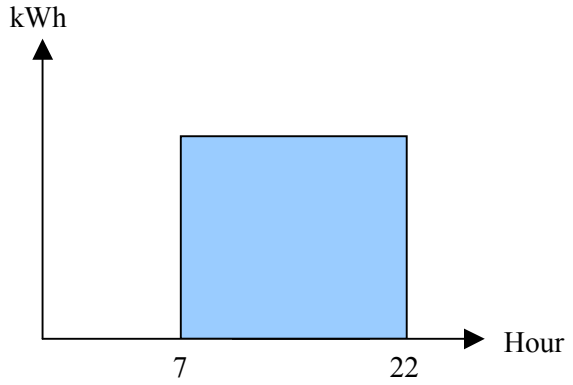
Hour Block 9, Summer Weekday and Peak Day



CO_2 ADER Parameters

Geographical Region	lbs/kWh
Northeast	-0.71
Midwest	0.25
Southeast	-0.01
Texas	0
West	0

Hour Block 10, Summer Weekend



CO_2 ADER Parameters

Geographical Region	lbs/kWh
Northeast	-0.87
Midwest	0.15
Southeast	-0.03
Texas	0
West	0

Step 3: Estimate Displaced Emissions

Displaced Emissions (lbs.) by Region

	Hour Block 4	Hour Block 5	Hour Block 9	Hour Block 10	Total
Electricity Displaced (kWh)	265	318	189	228	1,000
Northeast	-0.75*265 = -199	-0.82*318 = -261	-0.71*189 = -134	-0.87*228 = -198	-792
Midwest	0.21*265 = 56	0.18*318 = 57	0.25*189 = 47	0.15*228 = 34	194
Southeast	-0.02*265 = -5	-0.03*318 = -10	-0.01*189 = -2	-0.03*228 = -7	-24
Texas	-	-	-	-	-
West	-	-	-	-	-
Total	**-148**	**-213**	**-89**	**-171**	**-621**

--> With an assumed electricity savings of 1000 kWh, **621 lbs of CO_2** are displaced nationally in 2010

Conclusions

- ADER provides sound methodology for estimating displaced emissions
  - Captures the integrated response of power markets to changes in demand and/or supply
  - Flexible; can be applied to a wide range of energy efficiency and clean energy technologies
  - Relatively transparent
- However, some constraints:
  - Treatment of regulated pollutants
  - Geographic regions may be too large
  - Assumptions must be updated regularly
- ADER modeling is currently underway-results expected this summer
- Web tool to follow